Absorption spectroscopy of complex rare earth ion doped hybrid materials over a broad wavelength range

R. Dekker[1)], K. Wörhoff[1)], J.W. Stouwdam[2)], F.C.J.M. van Veggel[2)], and A. Driessen[1)].

[1)]University of Twente, Faculty of Electrical Engineering, Mathematics and Computer Science, MESA[+] Institute for Nanotechnology, P.O.Box 217, 7500 AE Enschede, The Netherlands.

[2)]University of Victoria, Department of Chemistry, P.O. Box 3065,Victoria, BC Canada V8W 3V6.

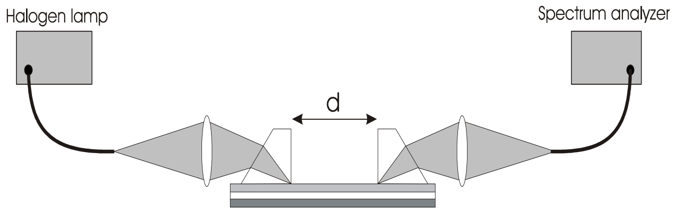
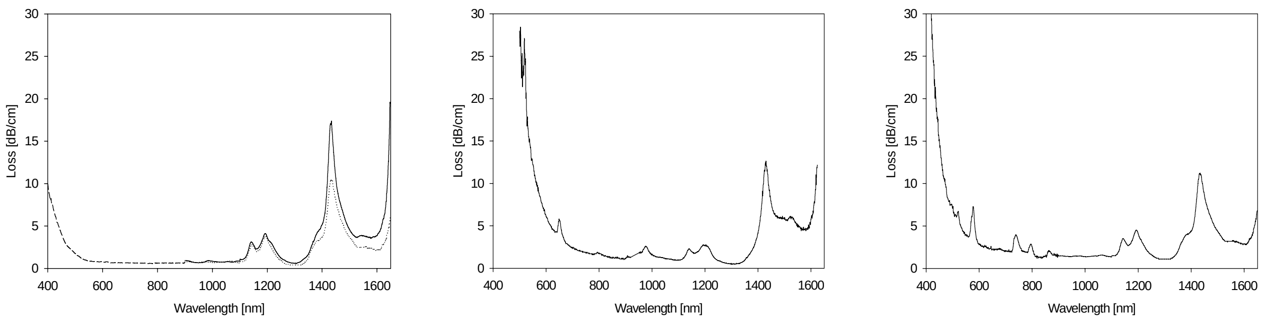


Figure 1: Measurement setup.

Absorption spectra have been measured by a fast and reliable loss characterization method that is based on a halogen light source, a dual prism setup and a spectrometer, see Figure 1. This equipment allows the rapid development of new hybrid optical materials for application in integrated optics. In the present work we applied this setup to determine several relevant properties of rare-earth doped nanoparticles dispersed in polymer slab waveguides in a single absorption measurement: background absorption of the polymer host material, water absorption, polymer composition (overtones), rare earth concentration, and ligand contribution (increase of exponential loss trend in the UV). Furthermore, nanoparticle size and concentration in case of a refractive index mismatch ($1/\lambda^4$ and r^6 dependence of Rayleigh scattering losses in the UV) could be extracted. The average time to obtain a full loss measurement is around 30 minutes, which provides fast feedback without the need to fabricate two-dimensional waveguides for cutback measurements.

In the following we concentrate on the characterization of erbium and neodymium doped lanthanumfluoride nanoparticles dispersed in a photo patternable polymer waveguide. These optically active nanoparticles are interesting for applications in integrated optical amplifiers [1]. By processing the recorded transmission spectra as function of prism separation *d*, the optical losses of the material can be obtained in the range from 400-1600nm. Figure 2 shows some typical loss spectra of an undoped polymer film (a), and polymer films with erbium doped (b), and neodymium doped (c) nanoparticles, respectively.



(a) undoped *(b) erbium doped* *(c) neodymium doped*

Figure 2: Loss spectra of a series of polymer thin film waveguides

The exponential loss (Urbach tail) can be clearly observed at short wavelengths in Fig. 2a as well as the 3rd CH overtones around 1175nm and the 2nd OH overtone around 1438nm. The CH absorption in Figure 2a remains constant while the OH absorption decreases (dotted line), as expected, after a short 100ºC-baking step to remove the absorbed water. Furthermore, the typical absorption lines of erbium (520nm, 660nm, 980nm and 1480-1550nm) and neodymium (532nm, 580nm, 745nm, 795nm, and 860nm) are clearly shown in Figure 2b and 2c, from which the rare earth concentration can be derived. The increased absorption at shorter wavelengths is not caused by scattering of the nanoparticles since its refractive index is matched by the polymer (n~1.59). The reason instead is the UV absorption of the yellowing ligands, which are attached to the nanoparticles.

[1] R. Dekker, D. J. W. Klunder, A. Borreman, M. B. J. Diemeer, K. Wörhoff, A. Driessen, J. W. Stouwdam, and F. C. J. M. van Veggel, "Stimulated emission and optical gain in LaF_3:Nd nanoparticle-doped polymer-based waveguides", *Appl.Phys.Lett.*, Vol **85**, No 25, pp. 6104-6106, 2004.